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Insect Pest Abundance on Sweet Basil, *Ocimum basilicum* L. (Labiatae) Under Different Production Systems

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ABSTRACT

Insect pests are often the major constraint for exportation of sweet basil. This study revealed the abundance of insect pests on sweet basil under organic, good agricultural practice (GAP) and conventional production systems in central Thailand from February 2010 to January 2011. In total, 6,886 pest specimens from 8 species were collected from all fields while only 2 species of natural enemies were recorded. In total, 4,119 individual insect pests were recorded in the organic field while the numbers in GAP and conventional fields were 1,418 and 1,349, respectively. In every sweet basil production system, thrips (*Bathrips melanicornis*) were the most common pest. In general, 8 out of 12 monthly diversity indices from the organic system were higher than those from either the GAP or conventional systems. The highest diversity index recorded from the organic farms was in August (1.63) while the highest diversity index from the GAP system (1.61) was recorded in September and from the conventional system (1.42) in October. Since Thailand is a global exporter of sweet basil, this study provides important reference information for importing countries, and represents a form of protection for sweet basil exports from Thailand to the global market.

Keywords: sweet basil, insect pest, organic field, GAP, conventional field

INTRODUCTION

Sweet basil (*Ocimum basilicum* L.; Labiatae) is a minor crop in terms of agricultural area but it is a popular and important ingredient of Thai cuisine as it is used for the preparation of various foods including pastas and other Italian foods (Joey, 2008). Thailand is a global exporter of sweet basil with exports in 2010 of 722,938 kg with a value of THB 23,894,453 or approximately USD 735,000 (Department of Agriculture, 2010). However, Department of Agriculture (2010) reported that in 2010 insect pests at the point of export were detected on basil 94 times while interceptions of insect pests at destinations notified by the European Union (EU) numbered 73. The majority of insect pests detected on sweet basil were the leaf miner fly (*Liriomyza sativae* Blanchard; Agromyzidae: Diptera) followed by the tobacco whitefly (*Bemisia tabaci* Gennadius; Aleyrodidae: Homoptera) and thrips (*Thrips* spp. Thripidae: Thysanoptera) according to Department of Agriculture (2010). Due to the frequent interception of these quarantine pests, they are considered serious problems, causing the EU to establish standard measures to certify the quality of imported sweet basil from Thailand.

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As a result, the Ministry of Agriculture and Cooperatives of Thailand issued a Notification entitled 'Stipulation of Plants to be Regulated' dated 29 April 2009. This notification stipulates that sweet basil has to be regulated prior to export to any destination and must be inspected for microorganisms and/or other contaminants that pose a risk to human health. In turn, the government agencies must transfer accumulated knowledge and information about pest biology, good agricultural practice and pest management techniques including postharvest technology to the farmers and exporters.

Prior to 1990, there were few reports on insect pests of sweet basil and then they only summarized previous records but provided no new information (Tigvattananont, 1990). Therefore, the present study of the insect pests on sweet basil and their abundance should contribute very important fresh information which should make it possible to prepare a list of insect pests found on sweet basil in Thailand. This is important reference information for importing countries, and represents a form of protection for sweet basil exports from Thailand to the global market.

MATERIALS AND METHODS

The experiments were conducted under three different production systems in Latbualuang district (14°6'33N", 100°14'53"E), Phra Nakhon Si Ayutthaya province located on the central plain of Thailand. The study sites were within an area of approximately 3 km^2. Latbualuang district is characterized by a relatively homogeneous landscape; most of the area is on a plain surrounding a river. There are 10 canals; therefore, this is a very rich area for agriculture. Of the total 19,800 ha, about 83% (16,418 ha) is devoted to agriculture. Average rainfall of 34.46 mm per month (Anonymous, 2013a) and an average temperature of approximately 30 °C were reported in the study region (Anonymous, 2013b).

The conventional production field under investigation was treated with agrochemicals including inorganic and organic fertilizers. For insect pest control, the field was sprayed preventatively, mostly based on a calendar spray program without pest monitoring. The following insecticides were used (Table 1): cypermethrin (Cypermethrin 10®; Mitsu Industries, Gujarat, India), lambda-cyhalothrin (Karate 2.5®; Syngenta, Greenboro, New York, USA) and deltamethrin (Decis®; Bayer CropScience Ag, Monheim am Rhein, Germany) and indoxacarb (Avatar®; Du Pont, Wilmington, Delaware, USA). Cypermethrin is a synthetic pyrethroid widely used by both large-scale, commercial agricultural production and small farms and behaves as a fast-acting neurotoxin against insects (Anonymous, 2015). Lambda-cyhalothrin is a contact insecticide

Table 1 Insecticides used under different basil production systems in Latbualuang district, Phra Nakhon Si Ayutthaya Province.

Insecticide	Application rates of active ingredient ($g.ha^{-1}$)		
	GAP	Conventional	Organic
Cypermethrin (Cypermethrin 10 EC®)	83.31	104.16	N/A
Lambda-cyhalothrin (Karate 2.5 EC®)	31.25	34.72	N/A
Deltamethrin (Decis®)	18.75	20.81	N/A
Chlorpyrifos (Chlorpyrifos 40 EC®)	N/A	694.44	N/A
Dimethoate (Dimethoate 40 EC®)	N/A	347.22	N/A
Pirimiphos-ethyl (Pirimiphos-methyl®)	N/A	694.44	N/A
Indoxacarb (Avatar®)	31.25	N/A	N/A

GAP = Good agricultural practice; N/A = Not allowed to be used.

against sucking and chewing herbivores (Bert, 2007). Other insecticides used in the conventional production system were chlorpyrifos (Chlorpyrifos 40®; Anhui Guangxin Agrochemical, People's Republic of China), dimethoate (Dimethoate 40®; Hui Kwang Chemical, Taiwan) and pirimiphos-methyl (Pirimiphos-methyl®; Hunan Haili Chemical Industry, People's Republic of China) as shown in Table 1. They all are organophosphorus compounds which bind to acetylcholinesterase and other cholinesterases resulting in disruption of nervous impulses, killing the insect or interfering with its ability to carry out normal functions.

The investigated field with a Good Agricultural Practice (GAP) production system was authorized under practical conditions and certified by the Department of Agriculture to be treated with both inorganic and organic fertilizers. For insect pest control, the field was monitored regularly to obtain information for decision-making and applying insecticide only when a pest population satisfied the criteria recommended by the Department of Agriculture. The insecticides used were cypermethrin, lambda-cyhalothrin, deltamethrin and indoxacarb. The last chemical was used for controlling Lepidopteran pests in certain vegetable and fruit crops.

By contrast, the field with the organic production system was cultivated according to the EU regulation (EEC No. 2092/91) based on the prohibition of inorganic fertilizers and synthetic pesticide applications.

The plant samples were collected and transported to the laboratory for identification of insects and other arthropods under a microscope at the Department of Entomology, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand.

Data collection

For each farm and each production system, a basil field was subdivided into 30 subplots of 1.15 × 1.90 m (15 plants per subplot) as shown in Figure 1. At 30 d after transplanting, basil plants in the vegetative growth stage from 10 randomly selected subplots were heavily trimmed and the cut parts (approximately 1 kg) were placed in plastic bags and transported to the laboratory and inspected for the presence of insects and other arthropods. The remaining 20 subplots were also heavily trimmed by the farm's owner for commercial sale. The sample collection from the new shoots of basil was repeated monthly for 12 consecutive months starting from February 2010 until January 2011.

Statistical analyses

The statistical analyses were performed using the SPSS software (Version 16.0; SPSS Inc.; Chicago, IL, USA). The diversities of insect pests and other arthropods were calculated using the Shannon-Weiner Diversity Index (H') according to Equation 1 (Magurran, 1988):

$$H' = -\sum_{i=1}^{n} p_i \ln p_i \quad (1)$$

where p_i is the proportion of individuals belonging to the i^{th} species/group and ln is the natural logarithm.

Pearson correlations were used to express the relationship between insect pests and pesticide usage.

RESULTS

Relationship between the abundance of insect pests and production system

In total, 6,886 pest specimens were collected from all fields during the 12 mth study period. There were 4,119 individual insect pests and natural enemies recorded in the organic field while the numbers in the GAP and conventional fields were 1,418 and 1,349 individuals, respectively (Figure 2a). The monthly data of insect pests found in the organic, GAP and conventional production systems during the observation period of 12 consecutive months are shown in Figure 2b. High pest numbers were observed on the organic farm in July (811) and September (815) in the middle of the rainy season and also in November (554) which was the beginning of the dry season. Natural enemies were observed during some months in fields under the organic production system and GAP system while none were found in the conventional system. However, the numbers of natural enemies were higher in the organic system (Figure 2c).

Relative abundance of insect pests and natural enemies under different production systems

The arthropod pests found on sweet basil under the different production systems in descending order of prevalence were: thrips (*Bathrips melanocornicus;* Thysanoptera), cotton aphid (*Aphis gossypii;* Aphididae), Ocimum leaf folder (*Syngamia abruptalis;* Pyralidae), lace bugs (*Monanthia globulifera;* Tingidae), false-spider mite (*Brevipalpus californicus;* Tenuipalpidae), mealybug (*Pseudococcus* spp.; Pseudococcidae), tobacco whitefly (*Bemisia tabaci;* Aleyrodidae) and leaf miner fly (*Liriomyza* spp.; Agromyzidae).

Thrips were the most abundant insect pest in all three production systems with totals of 3,060 individuals, followed by the cotton aphid (1,098) and Ocimum leaf folder (953) as shown in Figure 3.

Two species of natural enemies were found in the organic production system—ladybird beetle (*Coccinella* sp.; Coccinellidae) and fire ant (*Solenopsis geminata* F.; Formicidae)—but the numbers were very low. Under the GAP system, both these natural enemies were also recorded but the numbers were even lower. No natural enemies were observed under the conventional system. This clearly demonstrated that insecticide applications in the conventional fields affected the populations of natural enemies.

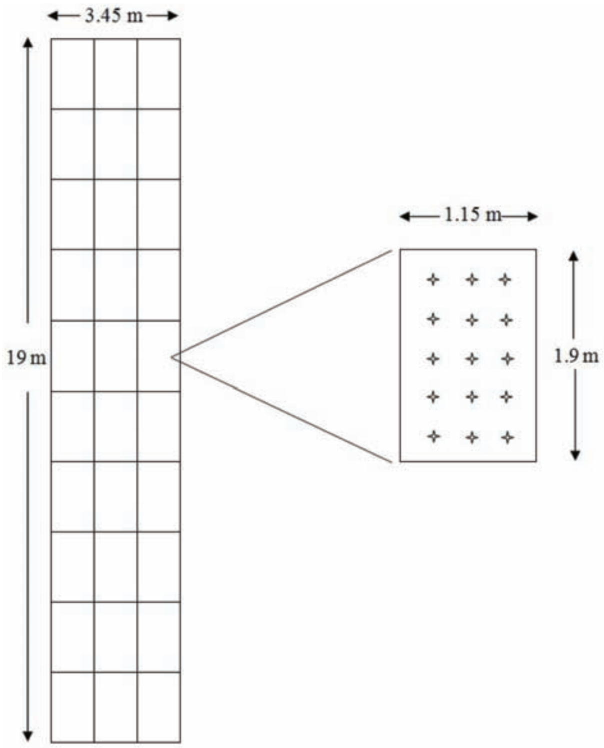

Figure 1 Plot layout (30 subplots with 15 basil plants per plot) of three different production systems in Singhanat municipality, Ladbualuang district, Phra Nakhon Si Ayutthaya province, Thailand.

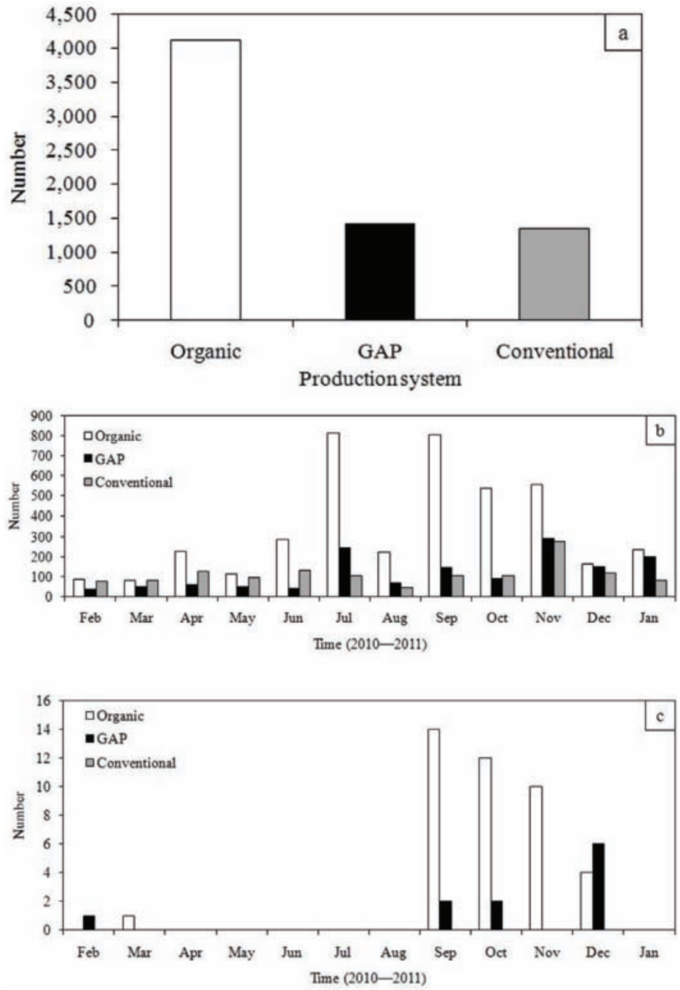

Figure 2 Insect pests abundance under organic, good agricultural practice (GAP) and conventional production systems: (a) Overall insect pests; (b) Insect pests over time; (c) Natural enemies over time.

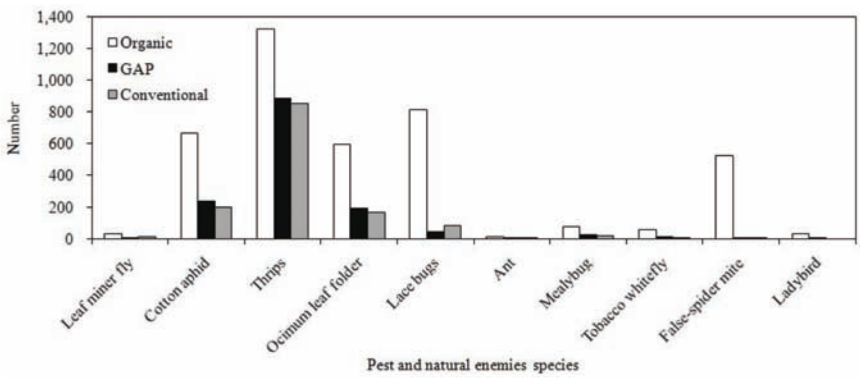

Figure 3 Relative abundance of insect pests under organic, good agricultural practice (GAP) and conventional production systems.

In general, 8 out of 12 monthly diversity indices from the organic system were higher than those from either the GAP or conventional systems (Figure 4). The highest diversity index recorded on the organic farms was in August (1.63) while the highest diversity index from the GAP system was 1.61 in September and 1.42 from the conventional system in October.

Insecticide treatments on good agricultural practice and conventional production system

Both the GAP and conventional fields were sprayed with insecticides before the start of the surveys. Four insecticides were allowed to be used under the GAP production system while six insecticides were used in the conventional field (Table 1). During the 12 mth study period, the numbers of insecticide applications in the conventional field were generally higher than those in the GAP field (11 out of 12 months). Consequently, the total grams of active ingredient per hectare (AI g.ha^{-1}) of insecticides applied onto the conventional field every month were more than that for the GAP field (Tables 2 and 3).

When the total numbers of insect pests found in each system were correlated with the total grams of active ingredient per hectare applied during the previous month using Pearson's correlation (r_s), the coefficients were very low and only the conventional field produced any statistically significant results ($r_s = 0.18$, $P = 0.04$) as shown in Table 4. This is not a surprising result since insecticides were applied as a preventative measure in both the GAP and conventional fields. In the organic field, no chemical insecticide was used and no correlation coefficient could be computed.

DISCUSSION

A total of eight pest species and two species of natural enemies were recorded on the sweet basil over the three production systems (GAP, conventional and organic). The use of pesticides for GAP systems is officially recommended or authorized under practical conditions and certified by the Department of Agriculture. Most of the sweet basil produced under the GAP system is exported to foreign countries (Department of Agriculture, 2010). In the conventional production system, the use of pesticide is determined by the farmer. Such practices usually create the potential to pollute the surrounding land, air and water (Adul *et al.*, 2011). Most of the sweet basil produced under conventional systems is consumed within Thailand (Department of Agriculture, 2010).

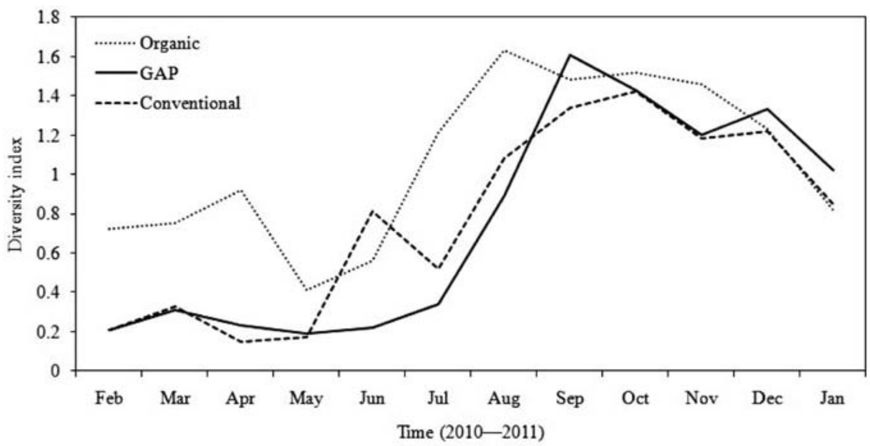

Figure 4 Diversity indices of insect (pests and natural enemies) under organic, good agricultural practice (GAP) and conventional production systems.

Thrips (*B. melanicornis*) are the most common pest in this system. The organic production system excludes or strictly limits the use of manufactured fertilizers and synthetic pesticides. The sweet basil grown under these conditions is mostly consumed within the country (Department of Agriculture, 2010).

The current results on the increased diversity and abundance of insects in organic farming confirmed those previously reported by Booji and Noorlander (1992), Bengtsson *et al.* (2005), Clough *et al.* (2007), Zehnder *et al.* (2007), Cotes *et al.* (2010), Adul *et al.* (2011) and Krauss *et al.* (2011). Insecticide spraying in conventional and GAP production systems did decrease the incidence of insect pests (Rundlöf and Smith,

Table 2 Insecticides applications and numbers of insect pests found under a good agricultural practice (GAP) production system.

Data/sample collection date	GAP production system				
	Number of insecticide applications during the month	Insecticide	Application rate ($g.ha^{-1}$ active ingredient)	Total insecticide used ($g.ha^{-1}$ active ingredient)	Total number of insect pests found
January 2010	2	Deltamethrin	18.75	50	N/D
		Indoxacarb	31.25		
February	2	Cypermethrin	83.31	114.56	38
		Lambda-cyhalothrin	31.25		
March	3	Deltamethrin	18.75	120.81	51
		Deltamethrin	18.75		
		Cypermethrin	83.31		
April	2	Deltamethrin	18.75	102.06	59
		Cypermethrin	83.31		
May	2	Deltamethrin	18.75	102.06	50
		Cypermethrin	83.31		
June	2	Cypermethrin	83.31	102.06	42
		Deltamethrin	18.75		
July	2	Cypermethrin	83.31	102.06	242
		Deltamethrin	18.75		
August	3	Indoxacarb	31.25	133.31	66
		Cypermethrin	83.31		
		Deltamethrin	18.75		
September	2	Cypermethrin	83.31	102.06	146
		Deltamethrin	18.75		
October	3	Indoxacarb	31.25	133.31	89
		Cypermethrin	83.31		
		Deltamethrin	18.75		
November	3	Indoxacarb	31.25	133.31	291
		Cypermethrin	83.31		
		Deltamethrin	18.75		
December	2	Cypermethrin	83.31	102.06	147
		Deltamethrin	18.75		
January 2011	N/D	N/D	N/D	N/D	197

N/D = No data.

Table 3 Insecticides application and numbers of insect pests found under conventional production system.

Data/sample collection date	Conventional production system				
	Number of insecticide applications during the month	Insecticide	Application rate (g.ha^{-1} active ingredient)	Total insecticide used (g.ha^{-1} active ingredient)	Total number of insect pests found
January 2010	3	Cypermethrin	104.160	833.32	N/D
		Lambda-cyhalothrin	34.720		
		Chlorpyrifos	694.440		
February	2	Cypermethrin	104.160	138.88	77
		Lambda-cyhalothrin	34.720		
March	4	Deltamethrin	20.810	180.50	81
		Cypermethrin	104.160		
		Lambda-cyhalothrin	34.720		
		Deltamethrin	20.810		
April	3	Cypermethrin	104.160	159.69	128
		Deltamethrin	20.810		
		Lambda-cyhalothrin	34.720		
May	4	Cypermethrin	104.160	263.85	96
		Lambda-cyhalothrin	34.720		
		Deltamethrin	20.810		
		Cypermethrin	104.160		
June	3	Cypermethrin	104.160	159.69	133
		Lambda-cyhalothrin	34.720		
		Deltamethrin	20.810		
July	3	Cypermethrin	104.160	159.69	105
		Lambda-cyhalothrin	34.720		
		Deltamethrin	20.810		
August	5	Lambda-cyhalothrin	34.720	888.85	44
		Chlorpyrifos	694.440		
		Cypermethrin	104.160		
		Lambda-cyhalothrin	34.720		
		Deltamethrin	20.810		
September	3	Lambda-cyhalothrin	34.720	173.6	104
		Cypermethrin	104.160		
		Lambda-cyhalothrin	34.720		
October	4	Deltamethrin	20.810	180.50	106
		Cypermethrin	104.160		
		Lambda-cyhalothrin	34.720		
		Deltamethrin	20.810		
November	4	Lambda-cyhalothrin	34.720	1097.19	277
		Dimethoate	347.220		
		Pirimiphos–methyl	694.440		
		Deltamethrin	20.810		
December	5	Lambda-cyhalothrin	34.720	958.29	116
		Pirimiphos–methyl	694.440		
		Cypermethrin	104.160		
		Deltamethrin	20.810		
		Cypermethrin	104.160		
January 2011	N/D	N/D	N/D	N/D	82

N/D = No data.

Table 4 Pearson correlation coefficients between total numbers of insect pests and pesticide usage under different production systems.

Production system	Pearson Correlation Coefficient (r_s)	*P*-value (significance using 2 tailed test)
Good agricultural practice	-0.045	0.608
Conventional	0.180	0.040*
Organic	N/D	N/D

* Correlation is significant at the 0.05 level (2-tailed).
N/D = No data.

2006) but only for a short period. After the residual effect of the insecticides had gone, the populations of insects in these fields increased.

The data presented here represent only one year of monitoring. However, they do raise several interesting questions. For example, would the peaks and troughs in the abundance of certain pests depicted in Figure 2 be consistent from year to year? Furthermore, if so, do they indicate that it may be necessary to pay special attention to inspection for particular pest species during their peaks? This is very important, especially in the case of basil exports. Safe and effective postharvest treatments may be necessary to eliminate all pests before export.

CONCLUSION

The organic production system contributed to the maintenance of biodiversity in agriculture and also enhanced species groups that provide ecosystem services with benefits to farmers due to a better top-down control of pest species. Therefore, the application of insecticides without prior information gained from monitoring insect pests will increase the direct management costs for farmers and their indirect costs due to reduced ecosystem services such as effective biological pest control.

In each production system, thrips (*B. melanicornis*) were the most common pest of sweet basil. This result was in general agreement with Sahaya *et al*. (2008) and Srikacha *et al*. (2008) who found aphids (*Aphi*s spp.), lace bugs (*M. globulifera*), mealybugs (*Pseudococus* spp.), tobacco whitefly (*B. tabaci*) and leaf miner fly (*Liriomyza* spp.) on sweet basil. The results are also consistent with the report that the larvae of the Ocimum leaf folder, *S. abruptalis* caused some damage to sweet basil in Thailand by feeding inside folded leaves (Tigvattananont, 1990). Finally, these field data are also consistent with the large number of quarantine interception records of thrips in the destination countries.

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